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# EUVE/XTE ORBIT DECAY STUDY

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## ABSTRACT

The Explorer Platform (EP) program currently comprises two missions, the Extreme Ultraviolet Explorer (EUVE) and the X-ray Timing Explorer (XTE), each of which consists of a scientific payload mounted to the EP. The EP has no orbit maintenance capability. The EP with the EUVE payload will be launched first. At the end of the EUVE mission, the spacecraft will be serviced by the Space Transportation System (STS), and the EUVE instrument will be exchanged for the XTE. The XTE mission will continue until reentry or reservicing by the STS.

Because the missions will be using the EP sequentially, the orbit requirements are unusually constrained by orbit decay rates. The initial altitude must be selected so that, by the end of the EUVE mission (2.5 years), the spacecraft will have decayed to an altitude within the STS capabilities. In addition, the payload exchange must occur at an altitude that ensures meeting the minimum XTE mission lifetime (3 years) because no STS reboost will be available.

Studies were performed using the Goddard Mission Analysis System to estimate the effects of mass, cross-sectional area, and solar flux on the fulfillment of mission requirements. In addition to results from these studies, conclusions are presented as to the accuracy of the Marshall Space Flight Center solar flux predictions.

## 1.0 INTRODUCTION

The Extreme Ultra-Violet Explorer (EUVE) will be housed on the Explorer Platform (EP) and launched in August 1991. This study is based on the following mission scenario:

> After a nominal 2.5-year mission, the Space Transportation System (STS) will rendezvous with the EP and replace the EUVE payload with the X-ray Timing Experiment (XTE). It is assumed that XTE will remain in orbit for at least an additional 3 years.

During the 5.5-year combined EP lifetime, the spacecraft altitude will gradually decrease, primarily because of the effects of atmospheric drag. This gradual decrease in altitude over time is called orbit decay.

The EP has no propulsion system and, thus, no capability of boosting to a higher altitude. No plans currently exist to raise its orbit during the payload exchange; therefore, the EP orbit over the entire 5.5 years will be determined by the initial EUVE altitude and by the rate of orbit decay.

To ensure that the second payload, XTE, remains in orbit for its nominal mission lifetime, EUVE must be placed in an initial orbit that is high enough to prevent the EP from reentering for at least 5.5 years after launch. Because the current maximum rendezvous altitude for the STS is 500 kilometers (km), the EP orbit must decay to 500 km or less by the end of 2.5 years to allow for payload changeout. The purpose of this study was to determine the constraints placed on the initial EUVE altitude by the combined mission requirements. The study was performed by modeling the orbit decay over a range of conditions to determine initial altitudes (EUVE epoch altitudes) that would meet all altitude requirements.

## 2.0 ANALYSIS

The rate of decay of a spacecraft's orbit is approximately proportional to the deceleration due to aerodynamic drag, $F_D/m$, where $F_D$ is the aerodynamic drag force and m is the spacecraft mass. $F_D/m$ is given by

$$F_D/m = (C_D A/2m)\ \rho V^2$$

where the ratio in parentheses is generally referred to as the ballistic coefficient, $\beta$. $C_D$ is the drag coefficient, A is the cross-sectional area, $\rho$ is the atmospheric density, and V is the spacecraft velocity relative to the atmosphere. For a spacecraft in a given orbit, the factors influencing the rate of orbit decay will be mass, area, drag coefficient, and atmospheric density. The first three of these are conveniently combined into the ballistic coefficient.

Atmospheric density depends on altitude and solar flux. During periods of high solar flux, the upper atmosphere absorbs energy and the atmospheric density increases. The Goddard Mission Analysis System (GMAS) uses the initial orbit, spacecraft parameters, and monthly values of the solar flux to compute and integrate the equations of motion and to predict the orbit decay over a specified period. The Harris-Priester atmospheric density model was used.

The study was performed using three spacecraft cross-sectional areas, three spacecraft mass combinations, and two solar flux levels. In all cases, the drag coefficient was assumed to be 2.2. The mass and area values used are listed in Table 1. These values were used to bound the problem until specific design data become available. This table defines the nine cases arising from combinations of mass and cross-sectional area.

The mass values used are based on each mission's nominal mass and contingency mass. For each mission, the nominal mass was used as a low-mass case, the nominal mass plus the contingency mass was used as a high-mass case, and the mean of these two was used as a median-mass case. Whenever one mass case (high, low, or median) was used for the EUVE portion of the mission, the corresponding mass case was used for the XTE portion of the mission.

The three spacecraft areas used were computed as the estimated spacecraft area and areas 20-percent higher and 20-percent lower than this value. EUVE and XTE were assumed to have the same average cross-sectional area. The masses and areas used to form the nine cases are listed below.

| EUVE Mass (kg) | XTE Mass (kg) | Spacecraft Area ($m^2$) |
|---|---|---|
| 2601.4 | 2844.0 (low mass) | 14.9 (nominal - 20%) |
| 2814.5 | 3114.4 (median mass) | 18.6 (nominal) |
| 3028.2 | 3387.4 (high mass) | 22.3 (nominal + 20%) |

Table 1. Parameters for Each Case Definition

| Case No. | Cross-Sectional Area ($m^2$) | EUVE | | XTE | |
|---|---|---|---|---|---|
| | | Mass (kg) | Ballistic Coefficient ($m^2/kg \times 10^{-3}$) | Mass (kg) | Ballistic Coefficient ($m^2/kg \times 10^{-3}$) |
| 1 | 14.9 | 2601.4 | 6.30 | 2844.0 | 5.76 |
| 2 | 18.6 | 2601.4 | 7.87 | 2844.0 | 7.12 |
| 3 | 22.3 | 2601.4 | 9.43 | 2844.0 | 8.63 |
| 4 | 14.9 | 2814.5 | 5.82 | 3114.4 | 5.26 |
| 5 | 18.6 | 2814.5 | 7.27 | 3114.4 | 6.57 |
| 6 | 22.3 | 2814.5 | 8.71 | 3114.4 | 7.88 |
| 7 | 14.9 | 3028.2 | 5.41 | 3387.4 | 4.84 |
| 8 | 18.6 | 3028.2 | 6.75 | 3387.4 | 6.04 |
| 9 | 22.3 | 3028.2 | 8.35 | 3387.4 | 7.24 |

The solar flux levels used were based on the August 21, 1987, Marshall Space Flight Center (MSFC) 97.7-percent and 50-percent solar flux predictions. These predictions are based on a statistical model using data from all previous solar cycles. In principle, there is a 50-percent chance that the actual solar flux will be below the 50-percent prediction, and a 97.7-percent chance that it will be below the 97.7-percent prediction. Figure 1 plots the solar flux prediction levels used as functions of time.

The assumptions made in this analysis are as follows:

- The total EUVE/XTE mission lasts 5.5 years.
- The EUVE mission duration is 2.5 years, from August 31, 1991, to March 1, 1994.
- The XTE mission duration is 3 years, from March 1, 1994, to March 2, 1997.
- The EUVE spacecraft is placed in a circular orbit with an inclination of 28.5 degrees on August 31, 1991.
- The payload changeout occurs on March 1, 1994, and must be performed at or below a 500-km altitude by the STS. The EP orbit remains unchanged.
- The EP has no boost capability and receives no boost from the STS.
- The XTE mission must be at or above 300 km at the end of the mission (5.5 years after launch). This is the altitude at which reentry was considered imminent.

The first part of this analysis consisted of determining the maximum and minimum EUVE launch epoch altitudes for each combination of mass, area, and solar flux. The maximum initial altitude was determined by searching for the highest EUVE launch altitude that would decay to 500 $\pm$ 1 km at the end of 2.5 years (the end of the EUVE mission).

The minimum initial altitude was determined by searching for the lowest EUVE epoch altitude that would decay to 300 $\pm$ 2 km at the end of 5.5 years. The spacecraft mass was changed to the XTE value during the propagation at 2.5 years from epoch, and restarted for an additional 3-year period.

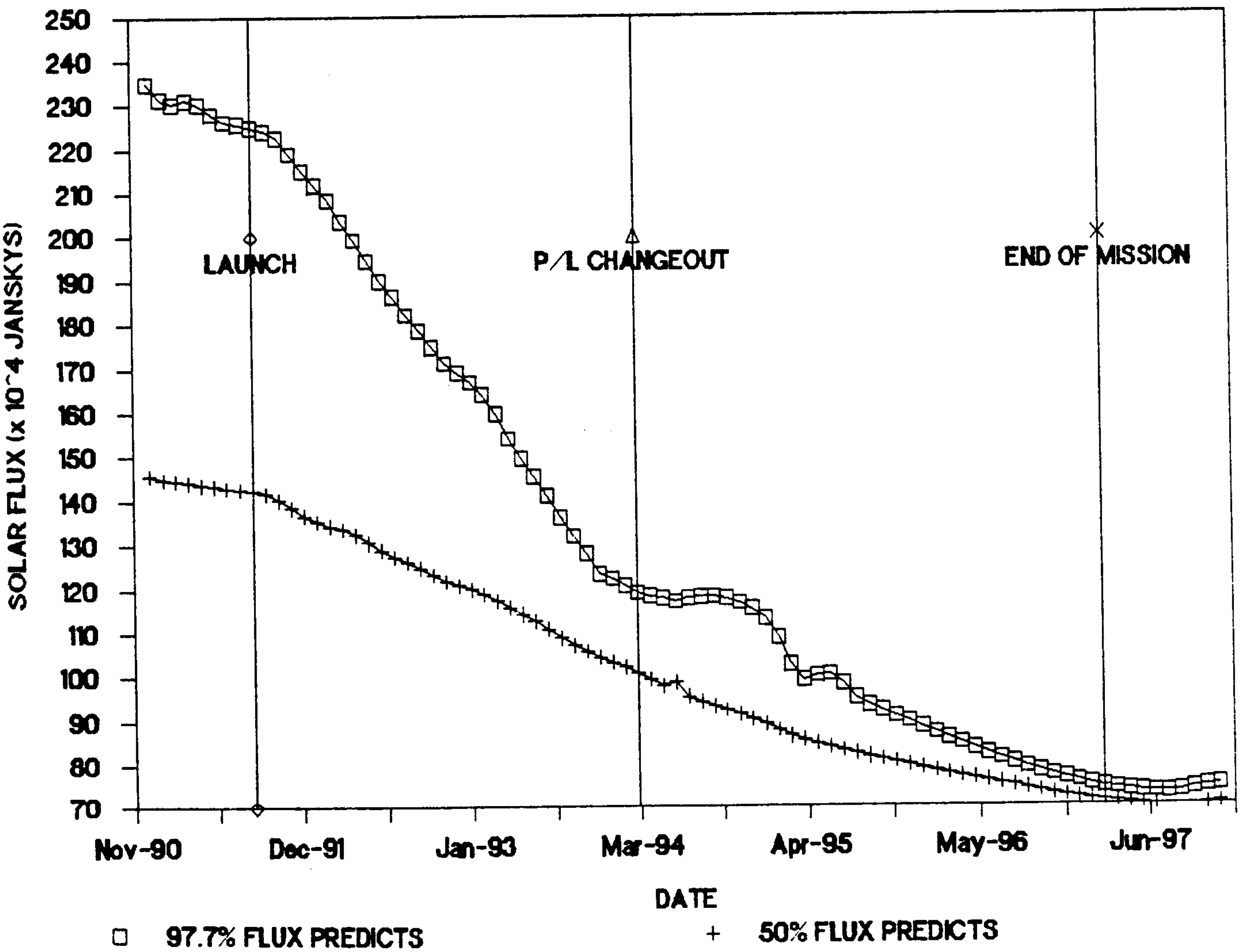


Figure 1. MSFC Solar Flux Predictions as of August 21, 1987

The maximum and minimum altitudes define an altitude band for each mass-area-flux combination; any altitude within the band will meet the mission requirements for the flux level used.

The 97.7-percent solar flux level is commonly used for mission planning as a worst-case scenario because the orbit decays faster at a higher flux level, and thus the mission life is shorter. However, because one EUVE/XTE mission requirement is that the EUVE spacecraft altitude be 500 km or less after 2.5 years, planning with the 97.7-percent solar flux level can mean that this goal is not met. If the flux level is actually much lower, 50-percent for example, the atmosphere will be less dense than predicted, and the orbit decay will be slower. Thus, the satellite would be above the 500-km maximum payload changeout altitude after 2.5 years. For this reason, two sets of altitude bands, corresponding to the 97.7-percent and the 50-percent solar flux levels, were determined for use in mission planning for each mass and area combination.

The second part of the study consisted of recomputing all the previous cases, using the exact same parameters including the initial altitudes, except that the flux level was changed to the alternate level. That is, all runs made at the 97.7-percent solar flux level were remade using the 50-percent solar flux level, and vice versa. The purpose of this half of the analysis was to illustrate the effects on planning with potential solar flux prediction error levels. These cases are the "what if" cases; they show what happens if the mission is planned using too high or too low a solar flux level and indicate the critical nature of the solar flux in mission planning, particularly near launch time, when commitment to a final launch altitude will be made.

The purpose of the third section of the analysis was to examine the accuracy of the MSFC solar flux predictions and, in particular, to determine whether the difference in predicted and actual values can be as great as between the 97.7- and 50-percent solar flux profiles used in the first two parts of this study. This was accomplished by examining MSFC predictions and actual data for the previous solar cycle. Using a 97.7-percent prediction and actual data from solar cycle 21, maximum and minimum initial altitudes were determined using the same method outlined above, assuming a launch on May 1, 1982. This launch date was chosen so that it occurred at the same place in relation to the cycle 21 solar peak as the current EUVE launch date is to the predicted solar peak. Then, as in the second half of the analysis, the orbit from both initial altitudes was propagated using the actual solar flux data.

## 3.0 RESULTS

The results of the study are summarized in Tables 2 and 3. In each table, the first column indicates the case number, corresponding to one mass-area-flux combination. Cases with the same mass and area have the same numerical part of the case number (e.g., 1 in 1A), while those with the same flux level have the same letter.

The second column contains the cross-sectional area for both spacecraft in square meters. The third and fifth columns contain the masses of the EUVE and XTE spacecraft, respectively, in kilograms. The fourth and sixth columns contain the ballistic coefficients, $\beta$, of the two spacecraft in square meters per kilogram.

The seventh column contains the EUVE epoch initial altitude in kilometers. The maximum altitude is on the top line for each case, and the minimum altitude is on the second line. The eighth and ninth columns contain the altitudes after 2.5 years and 5.5 years, respectively, in kilometers. The tenth and eleventh columns contain the altitudes reached using the same initial altitude but the alternate flux level.

Figure 2 illustrates the initial altitude band as a function of area and mass for both solar flux levels. The bands shown represent the acceptable altitude range for each of the nine cases at each flux level.

The effect of area on the altitude range can be seen by comparing consecutive cases that have the same spacecraft mass, such as 1A, 2A, and 3A. For this mass, an increase in cross-sectional area from 14.9 to 22.3 $m^2$ causes a 16-km difference in the maximum initial altitude required and a 28-km difference in the minimum initial altitude. The larger the area, the higher the altitude band must be. The range, or the size of the altitude band, is also affected by the area; it can be seen for the same cases that the smallest area allows a 29-km acceptable altitude band but the largest area decreases the acceptable altitude band to 17 km.

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Table 2. Upper and Lower Initial EUVE Altitudes at 97.7-Percent Flux Level

| Spacecraft Parameters | | | | | | | 97.7% Solar Flux | | 50% Solar Flux | |
|---|---|---|---|---|---|---|---|---|---|---|
| Case No. | X-Sect Area ($m^2$) | EUVE Mass (kg) | EUVE $\beta$ ($m^2$/kg $x10^{-3}$) | XTE Mass (kg) | XTE $\beta$ ($m^2$/kg $x10^{-3}$) | EUVE Epoch Altitude (km) | 2.5 Yr Altitude (km) | 5.5 Yr Altitude (km) | 2.5 Yr Altitude (km) | 5.5 Yr Altitude (km) |
| 1A | 14.9 | 2601.4 | 6.30 | 2844.0 | 5.76 | 547.10<br>**518.13*** | 499.99<br>434.47 | 479.88<br>301.34 | 532.25<br>494.49 | 524.30<br>479.16 |
| 2A | 18.6 | 2601.4 | 7.87 | 2844.0 | 7.12 | 555.68<br>533.54 | 500.05<br>445.96 | 473.78<br>301.51 | 538.98<br>509.79 | 529.96<br>494.89 |
| 3A | 22.3 | 2601.4 | 9.43 | 2844.0 | 8.63 | 563.44<br>546.44 | 500.00<br>455.58 | 466.81<br>301.46 | 545.22<br>522.63 | 535.33<br>508.09 |
| 4A | 14.9 | 2814.5 | 5.82 | 3114.4 | 5.26 | 544.31<br>**512.54*** | 499.97<br>429.82 | 481.89<br>300.93 | 530.12<br>488.86 | 522.64<br>473.50 |
| 5A | 18.6 | 2814.5 | 7.27 | 3114.4 | 6.57 | 552.41<br>527.82 | 499.83<br>441.20 | 476.23<br>301.55 | 536.34<br>504.02 | 527.79<br>489.10 |
| 6A | 22.3 | 2814.5 | 8.71 | 3114.4 | 7.88 | 559.98<br>540.61 | 500.02<br>450.74 | 470.54<br>301.55 | 542.42<br>516.75 | 533.02<br>502.18 |
| 7A | 14.9 | 3028.2 | 5.41 | 3387.4 | 4.84 | 541.85<br>**507.42*** | 499.99<br>425.63 | 483.58<br>301.70 | 528.26<br>483.72 | 521.21<br>468.34 |
| 8A | 18.6 | 3028.2 | 6.75 | 3387.4 | 6.04 | 549.66<br>**522.56*** | 499.95<br>436.87 | 478.67<br>301.26 | 534.22<br>498.73 | 526.13<br>483.78 |
| 9A | 22.3 | 3028.2 | 8.35 | 3387.4 | 7.24 | 556.89<br>535.25 | 500.04<br>446.32 | 473.54<br>301.88 | 539.94<br>511.35 | 531.00<br>496.75 |

* These initial altitudes satisfy requirements at both flux levels.

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Table 3. Upper and lower Initial EUVE Altitudes at 50-Percent Flux Level

| Spacecraft Parameters | | | | | | | 50 % Solar Flux | | 97.7% Solar Flux | |
|---|---|---|---|---|---|---|---|---|---|---|
| Case No. | X-Sect Area ($m^2$) | EUVE Mass (kg) | EUVE $\beta$ ($m^2/kg$ $x10^{-3}$) | XTE Mass (kg) | XTE $\beta$ ($m^2/kg$ $x10^{-3}$) | EUVE Epoch Altitude (km) | 2.5 Yr Altitude (km) | 5.5 Yr Altitude (km) | 2.5 Yr Altitude (km) | 5.5 Yr Altitude (km) |
| 1B | 14.9 | 2601.4 | 6.30 | 2844.0 | 5.76 | **522.09***<br>476.36 | 499.98<br>422.06 | 486.12<br>299.92 | 445.92<br>r 1.55yr | 373.80 |
| 2B | 18.6 | 2601.4 | 7.87 | 2844.0 | 7.12 | 526.66<br>489.25 | 499.97<br>432.76 | 482.11<br>301.39 | 421.15<br>r 1.47yr | r 4.19yr |
| 3B | 22.3 | 2601.4 | 9.43 | 2844.0 | 8.63 | 530.98<br>500.00 | 499.99<br>441.70 | 477.86<br>300.31 | 380.21<br>r 1.40yr | r 3.07yr |
| 4B | 14.9 | 2814.5 | 5.82 | 3114.4 | 5.26 | **520.63***<br>471.64 | 499.97<br>417.83 | 487.45<br>300.43 | 451.91<br>r 1.56yr | 401.31 |
| 5B | 18.6 | 2814.5 | 7.27 | 3114.4 | 6.57 | 524.97<br>484.41 | 500.00<br>428.38 | 483.92<br>301.78 | 431.78<br>r 1.48yr | r 4.99yr |
| 6B | 22.3 | 2814.5 | 8.71 | 3114.4 | 7.88 | 529.04<br>495.07 | 499.98<br>437.22 | 400.11<br>301.02 | 402.23<br>r 1.42yr | r 3.48yr |
| 7B | 14.9 | 3028.2 | 5.41 | 3387.4 | 4.84 | **519.73***<br>467.24 | 500.47<br>413.82 | 489.16<br>299.19 | 457.53<br>r 1.59yr | 418.97 |
| 8B | 18.6 | 3028.2 | 6.75 | 3387.4 | 6.04 | **523.46***<br>479.94 | 499.99<br>424.34 | 485.38<br>301.19 | 439.65<br>r 1.51yr | 330.55 |
| 9B | 22.3 | 3028.2 | 8.35 | 3387.4 | 7.24 | 527.33<br>490.50 | 499.98<br>433.04 | 481.98<br>300.67 | 416.46<br>r 1.44yr | r 4.00yr |

* These initial altitudes satisfy requirements at both flux levels.

NOTE: r x.xx yr means reentry after x.xx years

The effect of mass on the altitude band is also shown in Figure 2. Comparison of cases 1A, 4A, and 7A shows that an increase in mass (from lowest to highest) causes a difference of 5.25 km in maximum altitude required and a difference of 10.71 km in minimum altitude. An increase in mass also causes a slight increase in the range of acceptable altitudes. The total effect of the mass is about half that of the total effect of the area. The figure shows a uniformly increasing epoch altitude with increasing ballistic coefficient.

The effect of solar flux is also indicated in Figure 2. A cursory glance shows that the 97.7-percent solar flux level causes the altitude band to be higher than that defined for the 50-percent level. This is simply because the satellite will decay faster at a higher flux level, and thus the band needs to be higher to compensate. The altitude range is also shorter for the 97.7-percent flux level. Altitude selection is less flexible if the 97.7-percent solar flux level is used, and less room exists for orbit injection error.

Figures 3 and 4 illustrate orbital decay using the 97.7-percent and 50-percent solar flux levels for the median mass and nominal area cases (5A and 5B). The two solid lines in Figure 3 show the orbit decay from the maximum and minimum altitudes determined using the 97.7-percent solar flux (case 5A). The lines defined by the symbols correspond to the 50-percent flux level and show the orbit decay from the same altitudes if the solar flux is actually at the 50-percent prediction level. The mission constraints cannot be met using this maximum altitude if the flux level is 50-percent, because the satellite orbit does not decay to 500 km in the 2.5-year requirement; the minimum altitude shown almost meets the 500-km constraint with a 50-percent solar flux level (within 4 km). The minimum altitudes indicated with an asterisk in Table 2 meet the mission constraints ($\leq$500 km at 2.5 years and $\geq$300 km at 5.5 years) at both flux levels. No maximum altitudes determined using the 97.7-percent flux level will satisfy the mission requirements if the 50-percent flux level occurs.

Figure 4 is identical to Figure 3, except that the mission planning and the altitude band definition were made using the 50-percent flux level (case 5B). The maximum and minimum altitudes are depicted by the two solid lines, and the lines defined by the symbols correspond to the orbit decay if a 97.7-percent solar flux

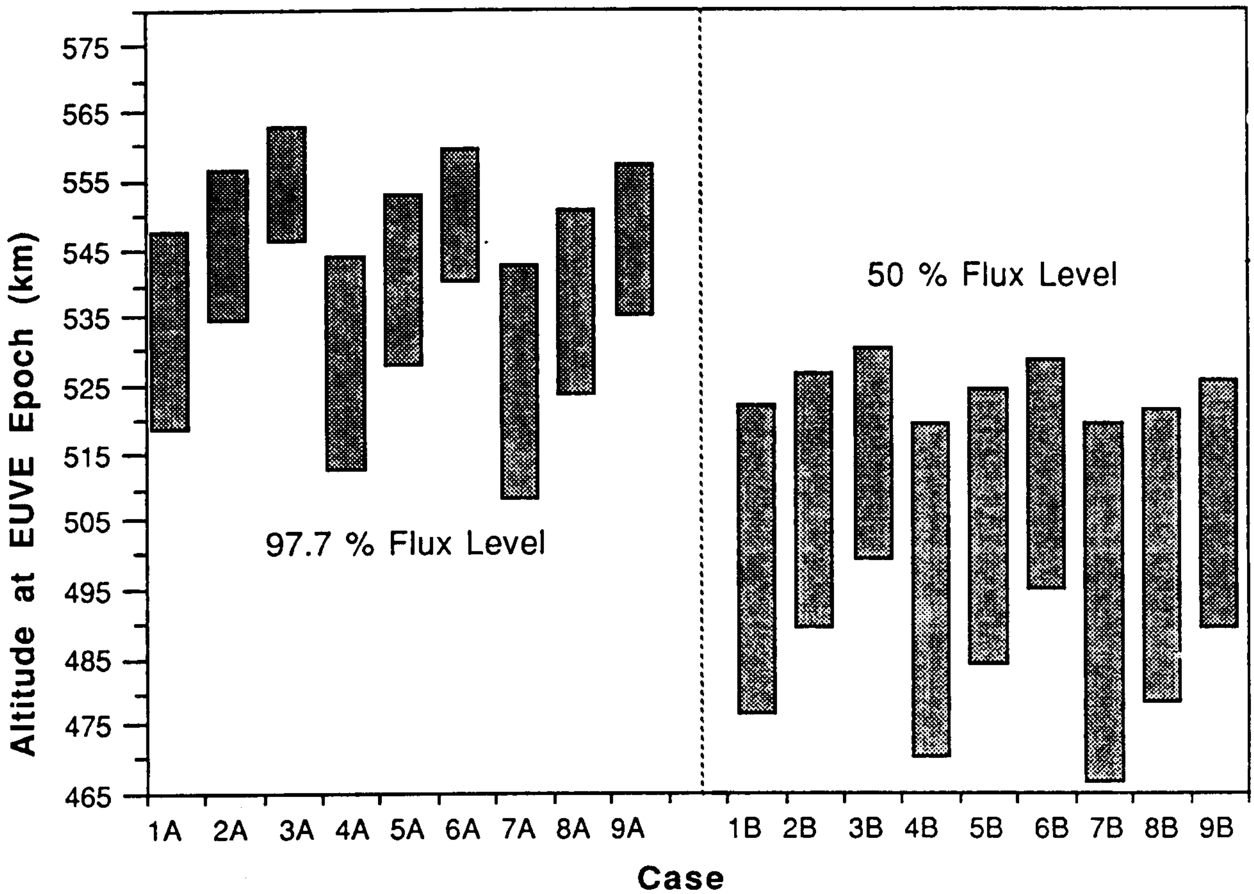


Figure 2. Altitude Ranges at Two Flux Levels (Altitudes in the Shaded Regions Meet Mission Requirements)

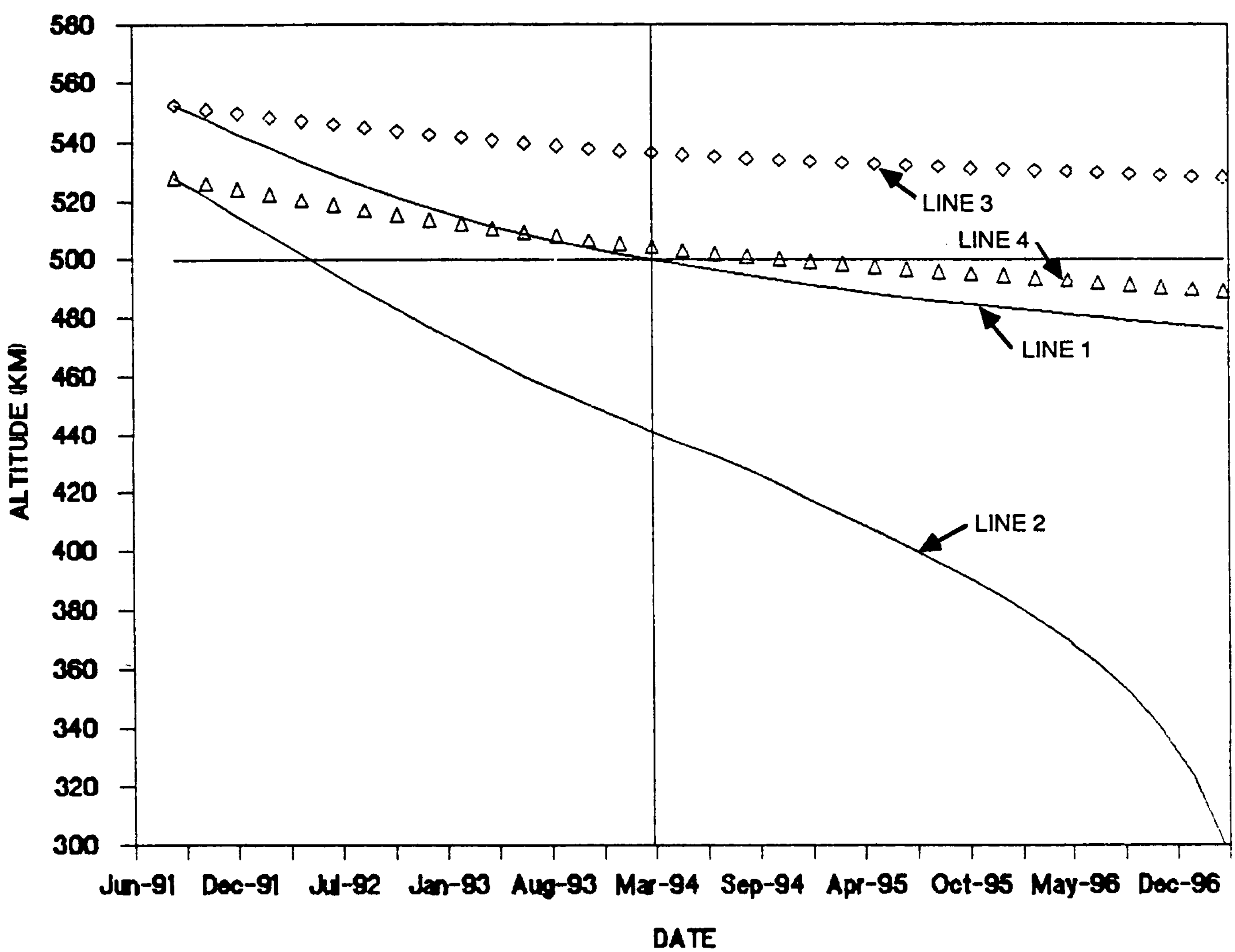


Figure 3. EUVE/XTE Orbit Decay Using 97.7-Percent Solar Flux

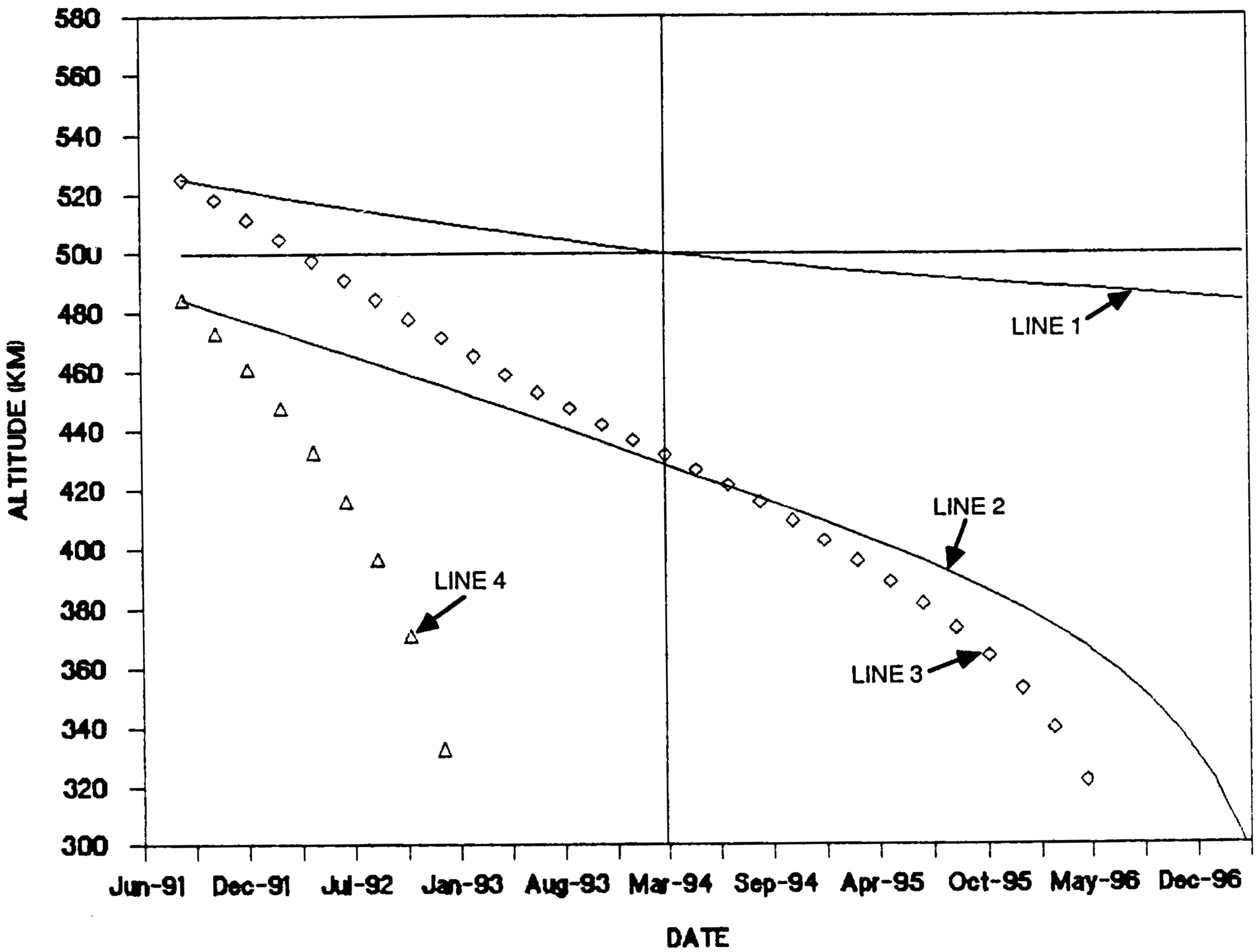


Figure 4. EUVE/XTE Orbit Decay Using 50-Percent Solar Flux

level is realized. If the actual flux level is 97.7-percent, the minimum EP lifetime (5.5 years) may not be met for the entire altitude band. The maximum altitudes in Table 3 that can satisfy both mission constraints are marked with an asterisk; no minimum altitudes calculated for the 50-percent flux level meet the mission requirements if the flux level is 97.7 percent. These graphs indicate what may happen if the solar flux level is not well known when final mission planning occurs.

The final altitude, at the end of 5.5 years, is extremely sensitive to the initial altitude, which can be seen by referring to Tables 2 and 3. For the median mass and nominal area (cases 5A and 5B), a comparison of the orbit decay from the maximum altitude for case 5B and the minimum altitude for case 5A, both with a 97.7-percent solar flux level, shows that a difference in initial altitude of 2.85 km can cause a 6-month difference in mission life. This can be seen graphically by comparing line 2 from Figure 3 to line 3 of Figure 4. This sensitivity is due in part to the end altitude of 300 km; if the satellite reaches 300 km too early, it will reenter very rapidly, in approximately 2 months. This sensitivity to initial altitude must be given serious consideration in planning the mission, and the area, mass, drag coefficient, and solar flux must be as well known as possible. It should be noted, however, that the sensitivity is decreased when the 50-percent solar flux level is used (only 4.02 km difference for the maximum altitude and 5.18 km for the minimum altitude in cases 5A and 5B).

Figure 5 shows the minimum and maximum EUVE launch epoch altitudes as a function of the EUVE ballistic coefficient at both flux levels. Because the XTE ballistic coefficients used in this study are linearly related to the corresponding EUVE ballistic coefficients, the arbitrary choice of EUVE parameters does not affect the results. The two bands shown in this figure represent the launch epoch altitude ranges at which mission requirements are met for the two flux levels. The bands overlap only in a small region. Only ballistic coefficients less than 0.0068 $m^2$/kg will meet the requirements at both flux levels, and then only launch epoch altitudes of approximately 496 to 518 km can be used. Outside this region, a deviation of flux level from the predicted level by the amount corresponding to the difference between the 97.7- and 50-percent levels will result in a failure to meet one or both of the mission requirements.

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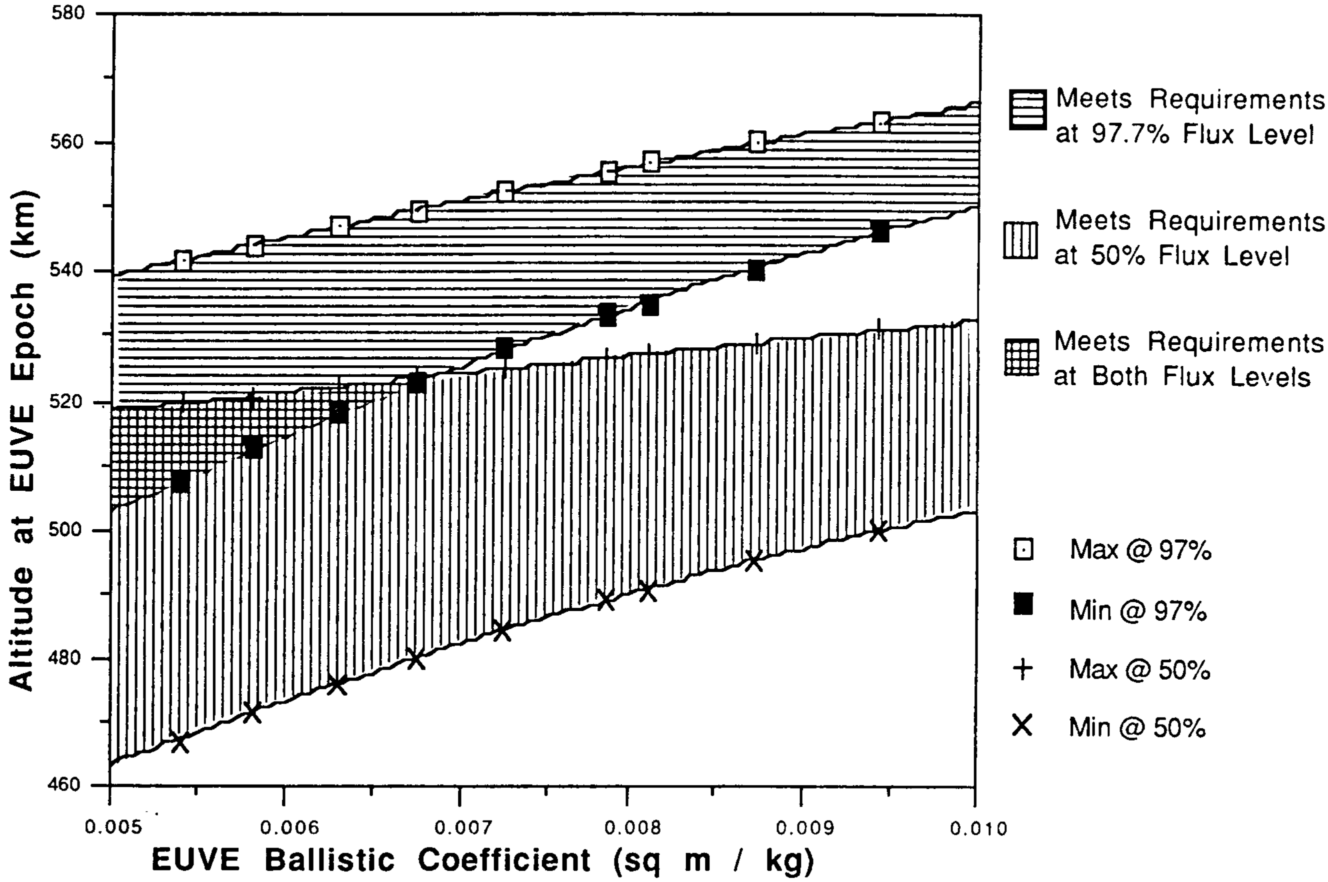


Figure 5. Range of EUVE Epoch Altitudes as a Function of Ballistic Coefficient

Figure 5 shows clearly that successful planning for the EP mission requires an uncertainty in flux-level predictions that is smaller than the difference between the 50- and 97.7-percent predictions used in this study for ballistic coefficients less than 0.0068. For this reason, the third part of the study was performed, to analyze the accuracy of MSFC predictions in the past, and to determine whether the difference in the 97.7- and 50-percent flux levels used above is realistic; that is, is it possible that MSFC predictions used for mission planning can have an error as great as that between the August 1987 97.7- and 50-percent prediction values.

Figure 6 illustrates the previous solar flux cycle (cycle 21) and two sets of MSFC predictions made for that cycle. The jagged line indicates the actual measured monthly values, and the dark line shows the 13-month smoothed data. The two thin lines above the smoothed data line are the 97.7- and 50-percent predictions made in April 1982. The two thin lines below the smoothed data are the 97.7- and 50-percent predictions made in September 1980. In both sets of predictions, the 97.7-percent predictions are higher than the 50-percent predictions. For cycle 21, the solar peak occurred in March 1981. A launch made in May 1982 occurs 14 months after the peak, the same time difference as between the EUVE launch and the predicted solar flux peak (cycle 22).

As shown in Figure 6, predictions made 2.5 years before a May 1982 launch would have underestimated the solar flux level; the results of a mission planned using the September 1980 97.7-percent solar flux predictions would be similar to those shown in Table 3 (the total mission lifetime would be shortened considerably). A more realistic scenario for a May 1982 launch would be to plan the mission using solar flux predictions made as close as possible to launch, in this instance, the April 1982 MSFC 97.7-percent predictions. Table 4 shows the initial altitudes determined for a May 1982 launch using the April 1982 97.7-percent prediction data, for the area and mass cases 2, 5, and 8. After the initial altitudes were determined, the cases were rerun using the actual 13-month smoothed solar flux data. The results are very similar to those shown in Table 2 for the same cases, although the minimum altitude always meets all mission requirements in the cycle 21 analysis. This suggests that the difference between the April 1982 97.7-percent predictions and the actual solar flux is close to the difference between the August

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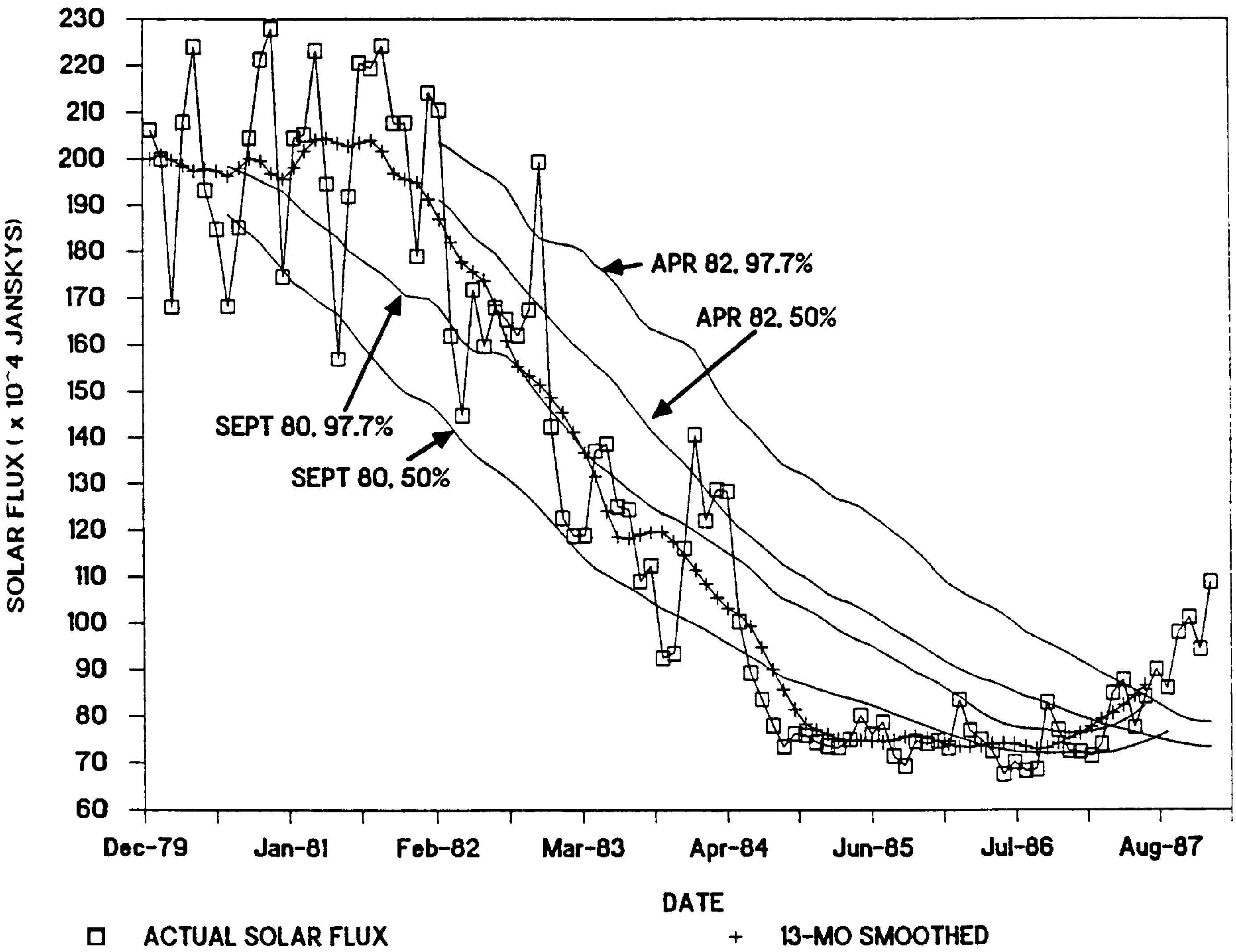


Figure 6. MSFC Solar Flux Prediction Comparison of Actual Data to 97.7- and 50-Percent Predictions

Table 4. Upper and Lower Initial EUVE Altitudes at April 1982 97.7-Percent Flux Level

| Spacecraft Parameters | | | | | | | 97.7% Solar Flux | | Actual Solar Flux | |
|---|---|---|---|---|---|---|---|---|---|---|
| Case No. | X-Sect Area ($m^2$) | EUVE Mass (kg) | EUVE $\beta$ ($m^2$/kg $x10^{-3}$) | XTE Mass (kg) | XTE $\beta$ ($m^2$/kg $x10^{-3}$) | EUVE Epoch Altitude (km) | 2.5 Yr Altitude (km) | 5.5 Yr Altitude (km) | 2.5 Yr Altitude (km) | 5.5 Yr Altitude (km) |
| 2C | 18.6 | 2601.4 | 7.87 | 2844.0 | 7.12 | 552.08<br>531.16* | 500.84<br>453.43 | 468.57<br>299.51 | 530.16<br>500.40 | 521.10<br>485.09 |
| 5C | 18.6 | 2814.5 | 7.27 | 3114.4 | 6.57 | 548.81<br>525.50* | 500.24<br>448.46 | 471.19<br>299.30 | 527.77<br>494.79 | 519.22<br>479.46 |
| 8C | 18.6 | 3028.2 | 6.75 | 3387.4 | 6.04 | 546.06<br>520.33* | 500.03<br>444.03 | 473.78<br>300.72 | 525.90<br>489.69 | 517.83<br>474.34 |

* These initial altitudes satisfy requirements at both flux levels.

1987 97.7- and 50-percent predictions. The MSFC predictions close to launch can be as inaccurate as the difference between these two flux-prediction levels.

## 4.0 CONCLUSIONS

The nominal GSFC Flight Dynamics Division (FDD) scenario for orbit lifetime early mission planning uses the 97.7-percent solar flux predictions. The result of using 97.7-percent solar flux predictions for mission planning while only a 50-percent solar flux level is realized is that the spacecraft may take longer than 2.5 years to reach the 500-km payload changeout altitude; therefore, either the XTE payload changeout will have to be delayed, or the STS will have to rendezvous with the EP at altitudes above 500 km, ranging from 545.22 to 502.18 km. If 50-percent solar flux predictions are used for mission planning and the flux is actually at the 97.7-percent flux level, the lifetime of both payloads will be severely jeopardized and, in some cases, the total lifetime of the EP would be shortened to 1.4 years. In such a case, the STS might have to rendezvous earlier than 2.5 years for payload changeout, and perhaps boost the EP spacecraft to a higher orbit to achieve the XTE mission objectives.

Because the goal of maintaining the spacecraft above 300 km for 5.5 years (and thus preventing early reentry) is more critical than reaching the changeout altitude after 2.5 years, the 97.7-percent solar flux level scenario should be used for early mission planning. In particular, the minimum altitude as determined using the 97.7-percent solar flux level should be used for mission planning because, in all cases, such an altitude can meet or can almost meet the midmission objective (500 km after 2.5 years) regardless of whether the solar flux level is at 50 percent or 97.7 percent.

However, as shown by Figure 6, even MSFC predictions made a month before launch can contain great uncertainties. The uncertainty in the MSFC solar flux predictions can be as great as the difference between the August 1987 97.7- and 50-percent levels used in this study. Any mission planning should accommodate such an uncertainty; an initial altitude selected would need to meet the 97.7- and 50-percent prediction levels to ensure meeting the mission goals. The GSFC FDD is currently investigating the use of solar flux predictions, made by GSFC Code 600, Sciences Directorate, which are based on models of physical phenomena as opposed to the statistical estimations made by MSFC. In the future, the FDD plans to use GSFC solar activity predictions for lifetime studies.

The solar flux level has the greatest effect on the EP mission lifetime, but the spacecraft cross-sectional area and mass also have significant effects. If the solar flux level uncertainty is as great as that indicated in this study, the ballistic coefficient plays a large role in determining an altitude to meet mission objectives. It may be necessary to add mass to adjust the ballistic coefficient to minimize the effects of uncertainty in solar flux predictions. The EP lifetime study should be updated as close as possible to launch, when the flux levels, the area, and the masses are better known. At that time, commitment to a final launch altitude will be made.

## REFERENCES


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